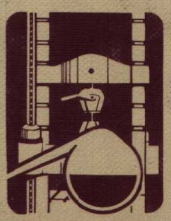
1991 ANNUAL BOOK OF ASTM STANDARDS



SECTION 3

Metals Test Methods and Analytical Procedures

ASTM

VOLUME 03.02 Wear and Erosion; Metal Corrosion

Revision issued annually

1991 ANNUAL BOOK OF ASTM STANDARDS

SECTION 3

Metals Test Methods and Analytical Procedures

VOLUME

03.02 Wear and Erosion; Metal Corrosion

Includes standards of the following committees:

G-1 on Corrosion of Metals
G-2 on Wear and Erosion

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Foreword

ASTM, founded in 1898, is a scientific and technical organization formed for "the development of standards on characteristics and performance of materials, products, systems, and services; and the promotion of related knowledge." It is the world's largest source of voluntary consensus standards.

The Society operates through 132 main technical committees with 2067 subcommittees. These committees function in prescribed fields under regulations that ensure balanced representation among producers, users, general interest, and consumer participants.

The Society currently has 32,800 members, of whom approximately 19,825 serve as technical experts on committees, representing 96,800 units of participation.

Membership in the Society is open to all concerned with the fields in which ASTM is active. A membership application may be found at the back of this volume. Additional information may be obtained from Member and Committee Services, ASTM, 1916 Race St., Philadelphia, PA 19103.

1991 Annual Book of ASTM Standards

The 1991 *Annual Book of ASTM Standards* consists of 68 volumes, divided among 16 sections, of which this volume is one. It contains formally approved ASTM standard classifications, guides, practices, specifications, test methods, and terminology and related material such as proposals. These terms are defined as follows in the Regulations Governing ASTM Technical Committees:

Categories:

standard—as used in ASTM, a document that has been developed and established within the consensus principles of the Society and that meets the approval requirements of ASTM procedures and regulations.

Discussion—The term "standard" serves in ASTM as an adjective in the title of documents, such as test methods or specifications, to connote specified consensus and approval. The various types of standard documents are based on the needs and usages as prescribed by the technical committees of the Society.

proposal—a document that has been approved by the sponsoring committee for publication for information and comment prior to its consideration for adoption as a standard.

Discussion—Complete balloting procedures are not required for proposals.

emergency standard—a document published by the Society to meet a demand for more rapid issuance of a specific standard document.

Discussion—The Executive Subcommittee of the sponsoring committee must recommend the publishing of an emergency standard and the Committee on Standards must concur in the recommendation. Emergency standards are not full consensus documents because they are not submitted to Society ballot.

Types:

The various types of ASTM documents are to provide a flexibility of form, communication, and usage for both the technical committees and the myriad users of ASTM documents. The type of ASTM document that is developed and titled is based on the technical content and intended use, not on the degree of consensus achieved. The three categories of ASTM documents (standard, emergency standard, and proposal) can be of the following forms and types:

classification—a systematic arrangement or division of materials, products, systems, or services into groups based on similar characteristics such as origin, composition, properties, or use.

guide—a series of options or instructions that do not recommend a specific course of action.

Discussion—Whereas a practice prescribes a general usage principle, a guide only suggests an approach. The purpose of a guide is to offer guidance, based on a consensus of viewpoints, but not to establish a fixed procedure. A guide is intended to increase the awareness of the user to available techniques in a given subject area and to provide information from which subsequent evaluation and standardization can be derived.

practice—a definitive procedure for performing one or more specific operations or functions that does not produce a test result. (Compare *test method.*)

Discussion—A practice is not a downgraded test method. Examples of practices include procedures for conducting interlaboratory testing programs or other statistical procedures; for writing statements on sampling or precision and bias; and for selection, preparation, application, inspection, necessary precautions for use or disposal, installation, maintenance, and operation of testing equipment.

specification—a precise statement of a set of requirements to be satisfied by a material, product, system, or service that indicates the procedures for determining whether each of the requirements is satisfied.

Discussion—It is desirable to express the requirements numerically in terms of appropriate units together with their limits.

terminology—a document comprising definitions of terms; descriptions of terms; explanations of symbols, abbreviations, or acronyms.

test method—a definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result. (Compare *practice*.)

A new edition of the Book of Standards is issued annually. Each volume contains all actions approved by the Society at least six months before the issue date. New and revised standards approved by the Society between the annual appearances of any given volume are made available as separate copies. The 1991 edition of the Book of Standards comprises approximately 53,000 pages and includes over 8600 ASTM standards.

Purpose and Use of ASTM Standards

An ASTM standard represents a common viewpoint of those parties concerned with its provisions, namely, producers, users, consumers, and general interest groups. It is intended to aid industry, government agencies, and the general public. The use of an ASTM standard is purely voluntary. The existence of an ASTM standard does not intend to preclude anyone from manufacturing, marketing, or purchasing products, or using products, processes, or procedures not conforming to the standard. Because ASTM standards are subject to periodic review and revision, those who use them are cautioned to obtain the latest revision.

Consideration of Comments on ASTM Standards

An ASTM standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of any standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

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Availability of Individual Standards

Each ASTM standard is available as a separate copy from ASTM. Special quantity prices and discounts for members can be obtained from Customer Services. When ordering, provide the ASTM standard designation and year of issue, title, quantity desired, and shipping instructions.

Obsolete Editions

This new edition of the *Annual Book of ASTM Standards* makes last year's edition obsolete. Each volume of the *Annual Book of ASTM Standards* is published annually because of additions of new standards and significant revisions in existing standards. On the average, about 30 % of each volume is new or revised. For practical purposes, therefore, it is not wise to use obsolete volumes. However, for teaching purposes, these outdated volumes might be useful.

Safety Hazard Caveat

In January 1990, the Board of Directors approved revisions to the ASTM Policy on Safety Precautions and modified the language of the generic caveat on Safety Hazards as follows:

This standard does not purport to address (all of) the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Inclusion of the caveat is required in test methods, specifications (where test methods are detailed other than by reference), practices, and guides.

Disclaimer of Liabilty as to Patents:

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in these standards. Users of these standards are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

ANNUAL BOOK OF ASTM STANDARDS

Listed by Section and Volume

ANNUAL BOOK OF ASTM STANDARDS
Listed by Subjects

List by Subjects

1991 ANNUAL BOOK OF ASTM STANDARDS, VOLUME 03.02

METALS—WEAR AND EROSION; METAL CORROSION

A complete Subject Index begins on p. 463

Since the standards in this book are arranged in alphanumeric sequence, no page numbers are given in this list by subjects.

The standards listed in italics are related documents included for information only and do not appear in this volume.

CORROSION

Test Methods for:

B 76 - 90	*Accelerated Life Test of Nickel-Chromium and Nickel-Chromium-Iron Alloys for Electrical Heating (see Vol 03.04)*
B 368 - 85 (1990)	*Copper-Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test) (see Vol 02.05)*
B 380 - 85 (1990)	*Corrosion Testing of Decorative Electrodeposited Coatings by the Corrodkote Procedure (see Vol 02.05)*
C 692 - 90	*Evaluating the Influence of Wicking-Type Thermal Insulations on the Stress Corrosion Cracking Tendency of Austenitic Stainless Steel (see Vol 04.06)*
B 651 - 83 (1988)	*Measurement of Corrosion Sites in Nickel Plus Chromium or Copper Plus Nickel Plus Chromium Electroplated Surfaces with the Double-Beam Interference Microscope (see Vol 02.05)*
F 483 - 90	*Total Immersion Corrosion Test for Aircraft Maintenance Chemicals (see Vol 15.03)*
G 57 - 78 (1984)$^{\epsilon 1}$	Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method
G 60 - 86	Conducting Cyclic Humidity Tests
G 61 - 86	Conducting Cyclic Potentiodynamic Polarization Measurements for Localized Corrosion Susceptibility of Iron-, Nickel-, or Cobalt-Based Alloys
G 87 - 84 (1990)$^{\epsilon 1}$	Conducting Moist SO_2 Tests
D 96 - 90	Corrosion in Plant Equipment (Electrical and Electrochemical Methods), On-Line Monitoring of
D 2776 - 79$^{\epsilon 1}$	Corrosivity of Water in the Absence of Heat Transfer (Electrical Methods) (Discontinued 1991†—Replaced by G 96)
G 41 - 90	Cracking Susceptibility of Metals Exposed Under Stress to a Hot Salt Environment, Determining
§G 34 - 90	Exfoliation Corrosion Susceptibility in 2XXX and 7XXX Series Aluminum Alloys (EXCO Test)
G 4 - 84	Conducting Corrosion Coupon Tests in Plant Equipment
G 104 - 89	Galvanic Corrosion Caused by the Atmosphere, Assessing
G 100 - 89	Galvanostaircase Polarization, Conducting Cyclic
G 97 - 89	Magnesium Sacrificial Anode Test Specimens for Underground Applications, Laboratory Evaluation of
G 51 - 77 (1984)	pH of Soil for Use in Corrosion Testing
G 48 - 76 (1980)$^{\epsilon 1}$	Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by the Use of Ferric Chloride Solution
F 746 - 87$^{\epsilon 1}$	Pitting or Crevice Corrosion of Metallic Surgical Implant Materials
§B 117 - 90	Salt Spray (Fog) Testing
G 103 - 89	Stress-Corrosion Cracking Test of Low Copper Containing Al-ZN-MG Alloys in Boiling 6 % Sodium Chloride Solution, Performing
G 28 - 85	Susceptibility to Intergranular Attack in Wrought, Nickel-Rich, Chromium-Bearing Alloys, Detecting
G 67 - 86	Susceptibility to Intergranular Corrosion of 5XXX Series Aluminum Alloys by Mass Loss After Exposure to Nitric Acid (NAMLT Test), Determining the
§G 47 - 90	Susceptibility to Stress-Corrosion Cracking of High-Strength Aluminum Alloy Products, Determining
G 37 - 90	Use of Mattsson's Solution of pH 7.2 to Evaluate the Stress-Corrosion Cracking Susceptibility of Copper-Zinc Alloys
G 66 - 86	Visual Assessment of Exfoliation Corrosion Susceptibility of 5XXX Series Aluminum Alloys (ASSET Test)
F 482 - 84	*Corrosion of Aircraft Metals by Total Immersion Maintenance Chemicals (see Vol 15.03)*
B 627 - 84	*Electrolytic Corrosion Testing (EC Test)(see Vol 02.05)*
C 876 - 91	*Half Cell Potentials of Reinforcing Steel in Concrete (see Vol 04.02)*

Practices for:

G 44 - 88	Alternate Immersion Stress Corrosion Testing in 3.5 % Sodium Chloride Solution
G 16 - 88	Applying Statistics to Analysis of Corrosion Data

† Although this standard has been officially withdrawn from Society approval, a brief description is included for information only.

§ Approved for use by agencies of the Department of Defense and, if indicated on the standard, replaces corresponding Federal or military document. Consult the *DoD Index of Specifications and Standards* for the specific year of issue which has been adopted by the Department of Defense.

Contents

1991 ANNUAL BOOK OF ASTM STANDARDS, VOLUME 03.02

STANDARDS RELATING TO METALS—WEAR AND EROSION; METAL CORROSION

A complete Subject Index begins on p. 463

Listed below are those standards included in this book and those standards that appeared previously that have been discontinued within the past five years. Since the standards in this book are arranged in alphanumeric sequence, no page numbers are given in this contents.

In the serial designations prefixed to the following titles, the number following the dash indicates the year of original issue as tentative or of adoption as standard or, in the case of revision, the year of last revision. Thus, standards adopted or revised during the year 1991 have as their final number, 91. A letter following this number indicates more than one revision during that year, that is, 91a indicates the second revision in 1991, 91b the third revision, etc. Tentatives are identified by the letter T. Standards that have been reapproved without change are indicated by the year of last reapproval in parentheses as part of the designation number, for example, (1991). A superscript epsilon indicates an editorial change since the last revision or reapproval—$^{\epsilon 1}$ for the first change,$^{\epsilon 2}$ for the second change, etc.

§ Approved for use by agencies of the Department of Defense and, if indicated on the standard, replaces corresponding Federal or military document. Consult the *DoD Index of Specifications and Standards* for the specific year of issue which has been adopted by the Department of Defense.

† Although this standard has been officially withdrawn from Society approval, a brief description is included for information only.

CONTENTS

RELATED MATERIAL

Designation: A 262 - 90

Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[1]

This standard is issued under the fixed designation A 262; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

These practices have been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 These practices cover the following six tests:

1.1.1 *Practice A*—Oxalic Acid Etch Test for Classification of Etch Structures of Austenitic Stainless Steels (Sections 3 to 7, inclusive),

1.1.2 *Practice B*—Ferric Sulfate-Sulfuric Acid Test for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels (Sections 8 to 14, inclusive),

1.1.3 *Practice C*—Nitric Acid Test for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels (Sections 15 to 21, inclusive),

1.1.4 *Practice D*—Nitric-Hydrofluoric Acid Test for Detecting Susceptibility to Intergranular Attack in Molybdenum-Bearing Austenitic Stainless Steels (Sections 22 to 28, inclusive), and

1.1.5 *Practice E*—Copper-Copper Sulfate-Sulfuric Acid Test for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels (Sections 29 to 38, inclusive).

1.1.6 *Practice F*—Copper-Copper Sulfate-50 % Sulfuric Acid Test for Detecting Susceptibility to Intergranular Attack in Molybdenum-Bearing Cast Austenitic Stainless Steels (Sections 39 to 45, inclusive).

1.2 The following factors govern the application of these practices:

1.2.1 Susceptibility to intergranular attack associated with the precipitation of chromium carbides is readily detected in all six tests.

1.2.2 Sigma phase in wrought chromium-nickel-molybdenum steels, which may or may not be visible in the microstructure, can result in high corrosion rates only in nitric acid.

1.2.3 Sigma phase in titanium or columbium stabilized alloys and cast molybdenum bearing stainless alloys, which may or may not be visible in the microstructure, can result in high corrosion rates in both the nitric acid and ferric sulfate-sulfuric acid solutions.

1.3 The oxalic acid etch test is a rapid method of identifying, by simple etching, those specimens of certain stainless steel grades which are essentially free of susceptibility to intergranular attack associated with chromium carbide precipitates. These specimens will have low corrosion rates in certain corrosion tests and therefore can be eliminated (screened) from testing as "acceptable."

1.4 The ferric sulfate-sulfuric acid test, the copper-copper sulfate-50 % sulfuric acid test, the nitric acid test, and the nitric-hydrofluoric acid test are based on weight loss determinations and, thus, provide a quantitative measure of the relative performance of specimens evaluated. In contrast, the copper-copper sulfate-16 % sulfuric acid test is based on visual examination of bend specimens and, therefore, classifies the specimens only as acceptable or non-acceptable.

1.5 In most cases either the 24-h copper-copper sulfate-16 % sulfuric acid test or the 120-h ferric sulfate-sulfuric acid test, combined with the oxalic acid etch test, will provide the required information in the shortest time. All stainless grades listed in the accompanying table may be evaluated in these combinations of screening and corrosion tests, except those specimens of molybdenum-bearing grades (for example 316, 316L, 317, and 317L), which represent steel intended for use in nitric acid environments.

1.6 For AISI Grades 316, 316L, 317, and 317L only, the nitric-hydrofluoric acid test may be used to provide test results in 4 h.

1.7 The 240-h nitric acid test must be applied to stabilized and molybdenum-bearing grades intended for service in nitric acid and to all stainless steel grades which might be subject to end grain corrosion in nitric acid service.

1.8 Only those stainless steel grades are listed in Table 1 for which data on the application of the oxalic acid etch test and on their performance in various quantitative evaluation tests are available.

1.9 Extensive test results on various types of stainless steels evaluated by these practices have been published in Ref **(10)**.[2]

1.10 The values stated in inch-pound units are to be regarded as standard. The SI equivalents are in parentheses and may be approximate.

1.11 *This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (Specific precautionary statements are given in 5.6, 11.1.1, 11.1.9, 25.1.4.1, and 42.1.)

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[1] These practices are under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and are the direct responsibility of Subcommittee A01.14 on Methods of Corrosion Testing.

Current edition approved Dec. 28, 1990. Published February 1991. Originally published as A 262 - 43 T. Last previous edition A 262 - 86.

[2] The boldface numbers in parentheses refer to the list of references found at the end of these practices.

TABLE 1 Application of Evaluation Tests for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

NOTE 1—For each corrosion test, the types of susceptibility to intergranular attack detected are given along with the grades of stainless steels in which they may be found. These lists may contain grades of steels in addition to those given in the rectangles. In such cases, the acid corrosion test is applicable, but not the oxalic acid etch test.

NOTE 2—The oxalic acid etch test may be applied to the grades of stainless steels listed in the rectangles when used in connection with the test indicated by the arrow.

OXALIC ACID ETCH TEST

AISI[A]: 304, 304L ACI[B]: CF-3, CF-8	AISI: 304, 304L, 316, 316L, 317, 317L ACI: CF-3, CF-8, CF-3M, CF-8M	AISI: 316, 316L, 317, 317L	AISI: 201, 202, 301, 304, 304L, 316, 316L, 317, 317L, 321, 347	ACI: CF-3M, CF-8M
Nitric Acid Test[C] (240 h in boiling solution)	Ferric Sulfate-Sulfuric Acid Test (120 h in boiling solution)	Nitric-Hydrofluoric Acid Test (4 h at 70°C)	Copper-Copper Sulfate-Sulfuric Acid Test (24 h in boiling solution)	Copper-Copper Sulfate-50 % Sulfuric Acid Testing Boiling Solution
Chromium carbide in: 304, 304L, CF-3, CF-8 Chromium carbide and sigma phase in:[D] 316, 316L, 317, 317L, 321, 347, CF-3M, CF-8M End-grain in: all grades	Chromium carbide in: 304, 304L, 316, 316L, 317, 317L, CF-3, CF-8 Chromium carbide and sigma phase in: 321, CF-3M, CF-8M[E]	Chromium carbide in: 316, 316L, 316LN, 316N, 317, 317L	Chromium carbide in: 201, 202, 301, 304, 304L, 316, 316L, 317, 317L, 321, 347	Chromium carbide in: CF-3M, CF-8M

[A] AISI: American Iron and Steel Institute designations for austenitic stainless steels.
[B] ACI: Alloy Casting Institute designations.
[C] The nitric acid test may be also applied to AISI 309, 310, 348, and AISI 410, 430, 446, and ACI CN-7M.
[D] Must be tested in nitric acid test when destined for service in nitric acid.
[E] To date, no data have been published on the effect of sigma phase on corrosion of AISI 347 in this test.

2. Referenced Document

2.1 *ASTM Standard:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

PRACTICE A—OXALIC ACID ETCH TEST FOR CLASSIFICATION OF ETCH STRUCTURES OF AUSTENITIC STAINLESS STEELS (1)

3. Scope

3.1 The oxalic acid etch test is used for acceptance of material but not for rejection of material. This may be used in connection with other evaluation tests to provide a rapid method for identifying those specimens which are certain to be free of susceptibility to rapid intergranular attack in these other tests. Such specimens have low corrosion rates in the various hot acid tests, requiring from 4 to 240 h of exposure. These specimens are identified by means of their etch structures which are classified according to the following criteria:

3.2 The oxalic acid etch test may be used to screen specimens intended for testing in Practice B—Ferric Sulfate-Sulfuric Acid Test, Practice C—Nitric Acid Test, Practice D—Nitric-Hydrofluoric Acid Test, Practice E—Copper-Copper Sulfate-16 % Sulfuric Acid Test, and Practice F—Copper-Copper Sulfate-50 % Sulfuric Acid Test.

3.2.1 Each practice contains a table showing which classifications of etch structures on a given stainless steel grade are equivalent to acceptable, or possibly nonacceptable performance in that particular test. Specimens having acceptable etch structures need not be subjected to the hot acid test. Specimens having nonacceptable etch structures must be tested in the specified hot acid solution.

3.3 The grades of stainless steels and the hot acid tests for which the oxalic acid etch test is applicable are listed in Table 2.

3.4 Extra low carbon grades, and stabilized grades, such as 304L, 316L, 317L, 321, and 347, are tested after sensitizing heat treatments at 1200 to 1250°F (650 to 675°C), which is the range of maximum carbide precipitation. These sensitizing treatments must be applied before the specimens are submitted to the oxalic acid etch test. The most commonly used sensitizing treatment is 1 h at 1250°F.

[3] *Annual Book of ASTM Standards*, Vols 01.01 to 01.05.

TABLE 2 Applicability of Etch Test

	AISI Grade No.	ACI Grade No.
Practice B—Ferric Sulfate-Sulfuric Acid Test	304, 304L, 316, 316L, 317, 317L	CF-3, CF-8, CF-3M, CF-8M
Practice C—Nitric Acid Test	304, 304L	CF-8, CF-3
Practice D—Nitric Hydrofluoric Acid Test	316, 316L, 317, 317L	...
Practice E—Copper-Copper Sulfate-16 % Sulfuric Acid Test	201, 202, 301, 304, 304L, 316, 316L, 317, 317L, 321, 347	...
Practice F—Copper-Copper Sulfate-50 % Sulfuric Acid Test	...	CF-8M, CF-3M